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G3P
Selected US specifications from IPC sub-classes G01M
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(54) Condition monitoring equipment for power output devices

(57) Power output devices such as thrusters, hydraulic rams, motor/gearbox combinations, and valve actuators are used in situations where the highest reliability is mandatory.

Condition Monitoring Equipment 5 uses a suitable transducer 6 to measure the output of such an output Device 1 in response to a command input at 2. This measurement is repeated at frequent intervals during the execution of the command, and from this series of measurements various parameters indicative of performance are calculated.

The equipment 5 may contain a model of the device 1, perhaps including the load 4 and associated control system (10), which in conjunction with the command (measured by a second transducer 7) is used to calculate the expected system response. From this calculated response is derived a set of target parameters, which are compared with the measured parameters.

By comparisons between the measured parameters and the target parameters, any malfunction or deterioration of performance can be detected, and displayed remotely 8 or locally 9.

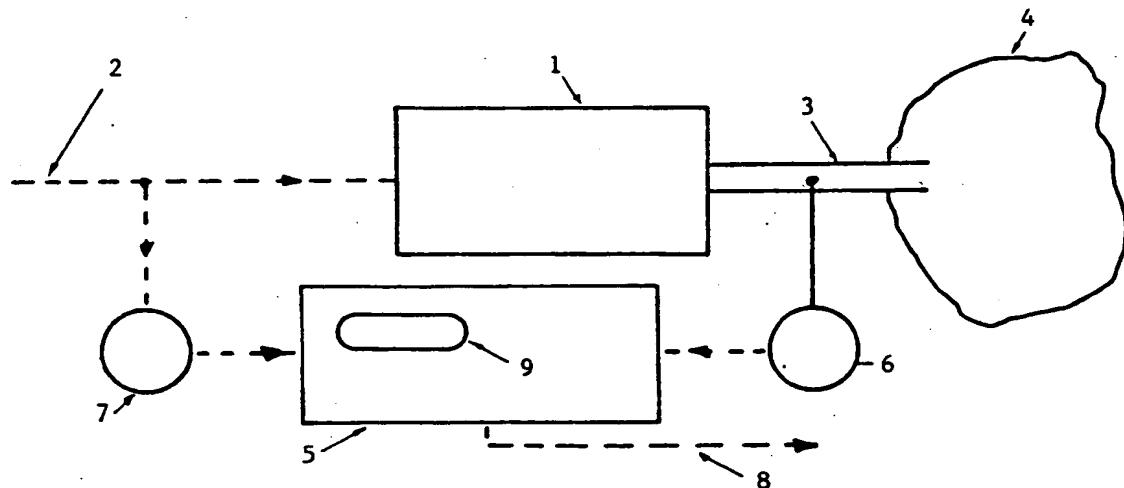


Figure 1

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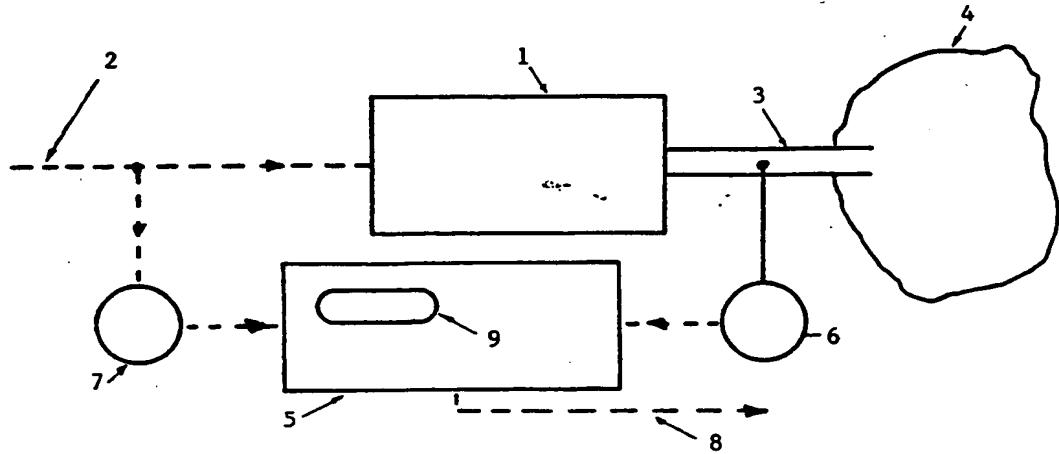


Figure 1

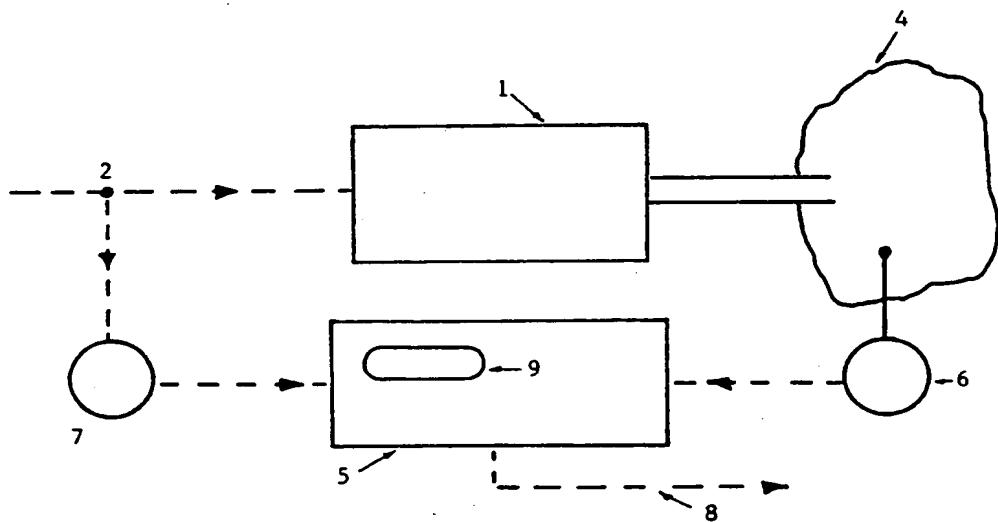


Figure 2

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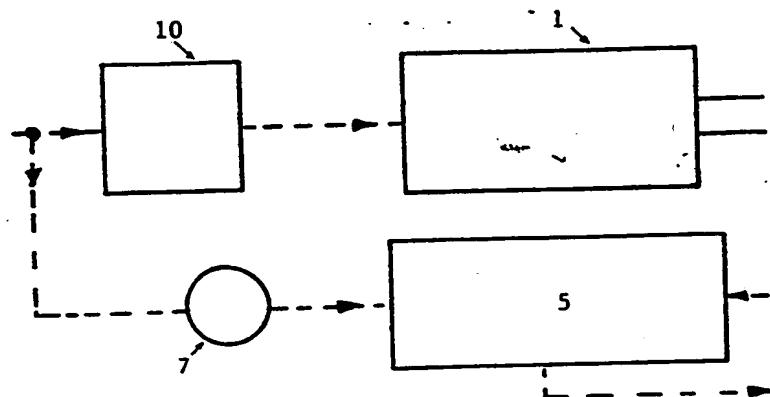


Figure 3

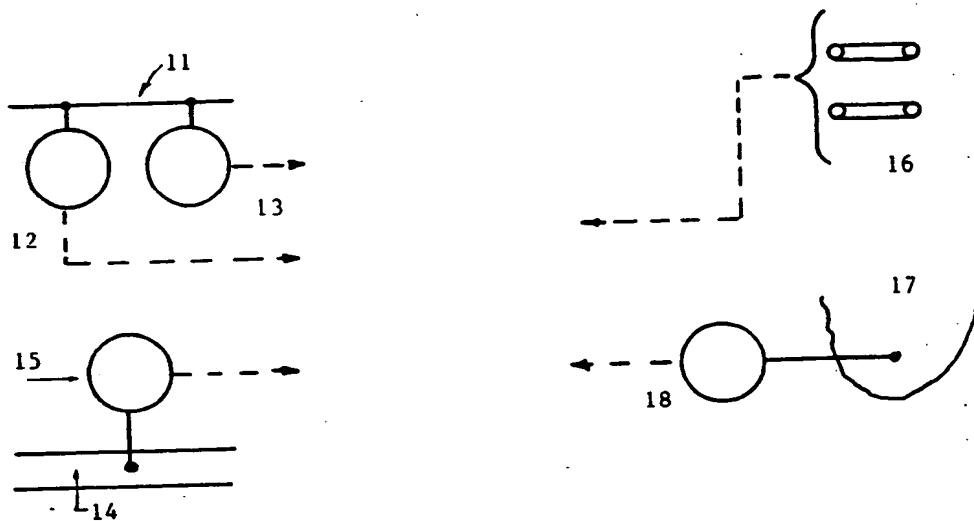


Figure 4

SPECIFICATION

Condition monitoring equipment for power output devices

5 Mechanical actuators, electromechanical power output devices, thrusters, hydraulic and pneumatic actuators, etc., are frequently used in applications where the highest reliability is 10 mandatory. This condition monitoring equipment analyses and response of the power output device to each command, looking for evidence of deterioration or failure.

The general arrangement is shown in Fig. 1. 15 The response of the device 1 being monitored is measured by means of some suitable transducer 6, (e.g. position, angular position, displacement or movement, according to the particular application), attached to the mechanical 20 output 3. The resultant electrical signal is taken to the condition monitoring equipment. 5. All incoming control signals to the mechanical device are copied to the equipment (with buffering to change voltage levels, provide 25 electrical isolation, convert from pneumatic or hydraulic signals to electrical signals, etc. as required). This interfacing is here shown provided by the transducer 7.

When the equipment detects a control signal to the mechanical device, it reacts by measuring the output of this device at frequent intervals, building up a "position profile" which consists of a set of readings of position, (or displacement, or angular position, or 35 some similar parameter), continuing until after the command has been executed and all movement has ceased.

This set of measurement is then analysed, in order to obtain information about the 40 response of the mechanical device to the command. Although the actual analysis may depend on the particular application, it would be normal to deduce from the position profile

- 1) The dead-time before the mechanical device starts to move.
- 2) The backlash on changing direction of movement.
- 3) The steady speed.
- 4) The over run after the command signal 45 has ended.
- 5) The smoothness (or irregularity) of motion.
- 6) The initial acceleration.
- 7) The time taken to reach a set proportion 55 of rated speed.
- 8) The overall movement which has taken place in response to the command.

The equipment makes use of, and in general 60 will contain within itself, a model of the actuator and the system to which it is coupled, from which is calculated the expected response to the command received by the power output device, and copied into the equipment, and from this calculated response 65 values of some or all of the parameters listed

above.

This model requires stored information from the last command, or last few commands, such as the direction of and magnitude of the last 70 movement. (This information is held in a store, generally within the equipment.)

The measured parameters are compared with those calculated from the command signal and the model, and used to generate a 75 "Figure of Merit" which is a measure of the closeness with which the real system complies with the model held within the performance monitoring equipment. The actual parameter weighting of this figure of merit will 80 depend upon the particular properties of the system to be scrutinised.

Local displays 9 will give an indication of changes in various parameters, and some or 85 all of these parameters may also be displayed remotely, possibly on some central data logging or alarm system 8.

Essentially, this "Figure of Merit" is to be used to classify the response of the actuator as

- 90 1) Normal
- 2) Showing signs of deterioration
- 3) Definite Malfunction

but more detailed classification of the results may be desirable in certain instances.

95 Several alternative configurations are possible: Fig. 2 shows that the movement of the system in response to a command to the actuator does not of necessity have to be measured at the point where the power is transmitted to the mechanical part of the system, but can be measured at some remote point.

100 Fig. 3 shows an application in which an electronic controller or signal decoding device 10 is included within the system under scrutiny. The model stored within the equipment is in this instance modified to describe the combined response of the control device, the actuator itself, and the mechanical system to 105 which it is coupled. This is primarily to enable the control or signal decoding device to be included within the parts of the system to be verified by this condition monitoring equipment.

110 115 Fig. 4 shows additional transducers which may be necessary for particular applications. If the actuating device is electrically powered, and fluctuations in supply (i.e. voltage and frequency) are to be expected, then the model 120 must be enlarged to take into account these fluctuations, which must be measured by an additional voltage transducer 12 and frequency transducer 13 shown connected to the power supply 11. Similarly, if the actuating device is 125 pneumatically or hydraulically powered, then it may be necessary to measure the pressure of the fluid supply 14 by means of a pressure transducer 15.

Varius additional switches or switch inputs 16 may be necessary to take into ac-

count changes in operating conditions, etc.

Where the system response is determined by any additional parameters, not already taken into account, then additional transducers 5 18 may be required to measure these parameters. For the purposes of this example these are shown schematically as originating in the mechanical part of the system 17.

In each of these cases the model which 10 simulates the system response must be modified to take into account the effect of these additional inputs.

The condition monitoring equipment may be extended to validate the incoming commands 15 to the system under scrutiny, for instance by comparing the duration and nature of these commands, and the intervals between commands, with preset limits contained within the equipment. The equipment may also be used 20 to detect improper or undesirable movements of the mechanical output when no command signal occurs, or in the interval between commands.

The equipment will contain a "watch-dog" 25 device, so that the equipment is to a very large extent self-checking. That is to say, any fault occurring within the equipment will be detected by the "watch-dog" device, and will generate an external error signal.

30 The model describing the response of the power output device and mechanical system to a command may be derived empirically, from observations of the response of a known good device to a series of commands, measured 'in situ', or it may be derived from separate performance tests carried out in a test rig or similar facility.

In the former case, the responses of the 40 observed device will be taken as the standard against which performance is compared.

In the latter case the testing of new systems would generally, although not essentially, be carried out by separate equipment, which 45 would generate the parameters to be used by the model in the monitoring equipment. (This method has certain advantages, in that (as an example) it may be easier to generate abnormal supply voltages, loads and conditions in a separate test facility than in the normal operating environment.)

50 These parameters may be entered into the equipment in any one of a number of ways familiar to those skilled in the applications of modern electronic devices. Obvious methods 55 include manually entering data via a keyboard, (permanent or attached only for the purposes of data entry), or storing data on memory devices, which are programmed in a separate test device, and then inserted into the equipment itself. Other methods of data transfer 60 could include data links, discs and data tapes.

CLAIMS

1. This equipment makes a frequently repeated series of output position measure-

ments during the period of execution of a command, and by examination of these measurements extracts information relevant to the condition of the system. This information is to include such values as total movement in response to a command, steady state speed, backlash on reversal overshoot or over-run, and smoothness of movement. It is envisaged that for new applications other (additional)

70 75 parameters may be found which will be of particular value in particular circumstances, and not all of the parameters listed may be required in every application.

2. This equipment as claimed in claim 1 is 80 particularly attractive in situations where any measurements are likely to be degraded by noise, or by the limited resolution and linearity of commercially available transducers, or by quantisation error, or when the movement 85 of the output is in itself a small part of the permissible range of travel.

This is particularly likely to be the case when monitoring the movement of control elements 90 during steady state conditions, in a variety of applications.

95 Not only does the multiplicity of measurements reduce the effect of non systematic error, but by using statistical or predictive algorithms it is possible extract the maximum information content from such degraded signals.

3. The equipment as claimed in claim 1 and in claim 2 embodies a model of the system, which calculates the response of the system to a measured command, and from this 100 calculated response derives the parameters particularly relevant to the condition of the system. The model is particularly valuable in that it may take into account permitted changes such as fluctuations in power supply 105 conditions and can be extended as necessary to take into account other quantities influencing the response of the system, such as variations in mechanical load, provided only that it is possible to measure these quantities, and 110 relate them deterministically to their effect upon system response.

4. The equipment as claimed in claim 1, claim 2 and in claim 3 carries out a comparison 115 between the parameter derived from the internally held model and the series of measurements and the results of this comparison is used to quantify the "merit" of the system, in terms of the closeness of the correspondence between the measured and calculated 120 parameters. This figure of merit takes into account all information extracted from the system, and can be weighted to take the greatest account of parameters found experimentally to 125 the most closely related to device deterioration, in a particular application.

5. The equipment as claimed in any preceding claim uses a model or simulation of the system to be monitored. This model may be empirical, based upon a multiplicity of observations, or mathematical, based upon a theo-

retical understanding of the system to be modelled, or any combination of these two cases. In this way, it is possible to extend the usefulness of this equipment to cover a plural-
5 ity of diverse applications.

6. The equipment as claimed in any preceding claim uses a method of analysis of information gathered using only simple transducers, likely to be both highly reliable and of
10 relatively low cost, and will permit machinery condition monitoring to be extended into fields where methods currently available are inadequate, either because of high transducer and equipment costs, or because the power levels
15 are insufficiently great for reliable measurement to be possible in a working environment, or because methods currently available do not yield sufficient information.

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